MEASUREMENTS OF ACOUSTIC WAVE PROPAGATION AND SCATTERING IN SHALLOW OCEANS AND A SEDIMENT SCATTERING MODEL

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LONG-TERM GOAL

To better understand the physics of acoustic/elastic wave propagation and scattering in shallow oceans and sediments at frequencies between 100 Hz and 100 kHz.

SCIENTIFIC OBJECTIVES

(1) To develop a universal (forward/inverse) model for the seafloor roughness scattering and the sediment volume scattering.
(2) To accurately measure the propagation and scattering of acoustic waves from the sediments.
(3) To determine how much of the attenuation with sediments is due to the viscosity of pore fluid, the shear wave conversion, and the scattering of acoustic waves.
(4) To accurately measure sediment properties accoustically including permeability, porosity, density, compressional and shear wave velocity and attenuation.

APPROACH

(1) The Yamamoto (1996) theory of sediment volume scattering will be combined with the Jackson et al. (1989) theory of seafloor roughness scattering.

(2) The high angular resolution bi-linear acoustic array developed at the Geoacoustics Laboratory (GAL) will be used to separate the head waves, sediment volume scattered waves, and scattered waves from rough sea-floor from incident waves. The bistatic scattering data from FY95 and the future experiment in FY97 will be used to test models.

(3) A new sediment model which includes the effect of macro-pores, and micro-pores in sediments will be developed. This theory will be tested by cross-well tomography experiments through various sediments.

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WORK COMPLETED

(1) A universal scattering model has been developed by combining the Yamamoto (1996) sediment volume scattering theory and the Jackson et al. (1986) sea-floor roughness model and tested by an at-sea experiment.

(2) The bistatic scattering data at 3.75, 7.5 and 15 kHz collected during the 1996 cruise have been analized.

(3) A new theory of elastic wave attenuation in sediment has been developed including the effects of the fluid-solid interactions in macro and micro pores. The theory has been tested by the cross-well tomography experiments through limestones of South Florida.

RESULTS

(1) The universal model has been compared with the measured bottom backscatter data at frequencies 3.75, 7.5 and 15 kHz collected using the UM-GAL bi-linear array during the cruse on the continental shelf near Fort Pierce, Florida in November, 1996. The sediment geoacoustic properties were measured using the Super Crosswell Tomography (SCWT) method (Rapids, Nye, and Yamamoto, 1997). The model-data comparison of bottom scatter gave an excellent agreement (Rogers and Yamamoto, 1997). Scattering from sediment volume velocity and density fluctuations dominate over the seafloor roughness scattering in most sediments for the grazing angle between the critical and the near normal for the 1 to 15 kHz.

(2) When used in the bi-static scatter measurement, the bi-linear 32 element acoustic array provides an excellent time-space resolution, enabling to separate head waves, sediment volume scattered waves, and rough seafloor scattered waves (Yamamoto et al., 1997, Day et al., 1997).

(3) The fluid motion in the micro pore in sediments induces viscoelastic behavior of the sediment frame. The viscous dissipation of pore fluid in the macro pore coupled with the viscoelastic micro pore structure of sediments are the two major attenuation mechanisms of acoustic and seismic waves in the sediments in the low to intermediate frequencies (10 Hz to 50 kHz). The attenuation of high frequency energy (50 kHz to 1 MHz) is primarily due to the viscoelastic behavior of the micro pore. (Yamamoto and Kuru, 1997).

The permeability image within sediments was extracted from the velocity and attenuation image measured by SCWT for the first time. The permeabiltiy values at four different depth interval measured by pumping tests agreed excellently with the SCWT image (Yamamoto and Kuru, 1997).

IMPACT/APPLICATIONS

(1) The invention of the bi-linear accoustic array will greatly improve acoustic scattering measurements because of its high spacial and temporal resolution power with a flaction of the required measurement time of conventional scattering measuremnt devices.

(2) The Super Crosswell Tomography method is providing new, economical means of imaging the structure of sediment properties, permeability in particular. The Japan Marine Science and Technology Center (JAMSTEC) held a special international workshop on SCWT in December, 1996 (Kinoshita, H., 1996). JAMSTEC and RSMAS exchanged the Memorandum of Understanding for co-operation on SCWT in order for JAMSTEC to be able to use SCWT as a standard operation of the Ocean Drilling Program in the 21st century (OD 21).

TRANSITIONS

(1) The Yamamoto (1996) theory of sediment volume scattering has became a standard model of the Navy acoustic scattering predictions in 6.2 and 6.3 communities through Dr. Andy Rogers of Planning Systems, Inc (PSI).

(2) The SCWT method has been given the most significant accomplishment award in 1995 by the Sociewty of Exploration Geophysicists (SEG) ; SEG desplayed theSCWT images at the 1997 Annual Meeting of, November, 1997, Dallas, TX. SCWT has made significant contributions to oil and groundwater exploration as well as to ocean acoustics.

RELATED PROJECTS

(1) The South Florida Water Management District is commissioned to measure the permeability structure of aquifers of the South Florida. Through a successful demonstration test of SCWT, the SFWMD and the UM-GAL will cooperate in the common interst of imaging the permeability structure within the sediments.

(2) JAMSTEC has started a 15 year super project to image the oceanic crust in attempt to better understand the reccurence of chatastrofic earthquakes and will soon start another super project called Ocean Drilling Program 21.

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